Introduction of a Model-Based Approach to Psychology Class: Class Practice for Serial Position Effect Experiments

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***Abstract*—We report an example class practice that introduces the model-based exercises into a psychology class in which participants investigate the serial position effect of the human memory. To the class, a rule-based cognitive model that simulates human memory processes was introduced. The participants themselves manipulated the parameters of the model and performed simulations that examined psychological experiments with a variety of experimental settings and experiments by participants of various working memory capabilities. Analysis confirmed that about two-thirds of the participants experienced good exploration processes and successfully compiled the research reports.**

Keywords - science education; model-based approach; serial position effect

I. INTRODUCTION

In science education, simulations using computer-executable models are widely used. For example, phET at the University of Colorado has released simulations developed based on science education research. Rutten et al. also reviewed studies on simulation-based learning and reported that is widely adopted in biology, physics, science, engineering, general science, earth sciences, and information science [1].

In this study, we report a simulation-based university class design and the results of its practice in psychology education. Compared to the vast practice in natural sciences, simulation-based class practices in psychology have been reported only in very limited cases. The current study focuses on cognitive psychology and cognitive science, which seek to understand the human internal processing mechanisms. In this field, as in other empirical sciences, computer models also play an important role as research tools.

In natural science, models are used not only in research but also in education for learning about various scientific phenomena. However, in psychology education, models are rarely used in class contexts; rather experience-based learning with experiments and observations is more popular. The model-based approach realizes the human internal processing mechanisms on a computer; and it is thought that by such models, unobservable internal processes can be objectively understood with the use of these models. This nature of computer modeling may enable students to learn about psychological phenomena more deeply and precisely.

Jong distinguishes between simulations that are based on conceptual versus operational models [2]. Conceptual models include principles and concepts in the system, and operational models include procedures and perform information processing. Jong points out that science education has focused on various conceptual models. In contrast, this study focuses on operational models that deal with how information is processed based on the internal mechanism. Both types of models exist in cognitive psychology and cognitive science, but in the information processing approach, models that reveal how information is processed in the internal mechanism take the leading role.

Example learning environments reported in preceding studies that support the construction of operational models in science education include DynaLearn [3] and Model-It [4] for understanding the dynamic behavior of environmental systems. For example, Model-It is intended for building ecosystem models, where learners can define specific objects such as animals, plants, and water, as well as define static and dynamic relationships between those objects. In the operational models in these previous studies, static, and dynamic relationships between multiple components are defined by mathematical formulas and graphs.

On the other hand, operational models related to the human cognitive processing describe not the definition of the relationship between components but rather the operations that transit the internal or external states. In the studies of human cognition, descriptions and understandings related to such operations are extremely important. For example, research on traditional human problem-solving analyzes cognitive processes by describing internal or external actions and state transitions that occur through the operations [5].

The subject of the lesson practice in this paper is the serial position effect in the human memory [6]. In Section 2, we explain the serial position effect, the computational model used for practice, and summary of our class practice. Followed by the section, we report two class practices in Sections 3 and 4, respectively. Section 5 is the discussion and conclusions section.

II. SERIAL POSITION EFFECT

The research topic, the serial position effect, observed in human memory experimentation will be briefly explained.

A. Primacy and recency effects

The serial position effect is a phenomenon in which, when a list of words is sequentially stored and free reproduction

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is performed, the memory performance of the first and last several items in the list is higher than the performance of the items presented in the middle of the list. The effect of the head of the list is called the primacy effect, and the effect of the ending is called the recency effect. These effects are recognized as robust experimental evidence that distinguishes between the short-term and long-term memory.

An established theory of the human memory system is summarized as follows. Information from the outside world is temporarily stored in the iconic memory. Information selectively focused on the iconic memory is sent to the short-term memory; however, it is maintained only for about 15 to 30 seconds. Without rehearsals of the items, they are soon erased from short-term memory. Through rehearsal processes, information in the short-term memory is encoded into the long-term memory. Once information is encoded in the long-term memory, it is never forgotten.

The primacy effect emerges because only words presented earlier are encoded into long-term memory through rehearsals. The recency effect appears because words from the end remain in the short-term memory and are directly retrieved from it when asked to be reported. In contrast, words in the middle of the list have been present too long to be held in short-term memory, but not long enough to be encoded into long-term memory.

B. Two storage model

The mechanisms of the short- and long-term memory, and the interaction of the two have been explained as the dual-storage model theory. In this study, based on the theory, a rule-based model that reproduces the serial position effect experiment was constructed. A computational architecture for cognitive modeling used in this practice was DoCoPro, an educational production system architecture developed by the authors [7].

Table I shows the main rules that construct the model. Figure 1 shows flows of cognitive information processing performed by the model. The model has several parameters. Students, by manipulating these parameters, are able to simulate the cognitive information processing of experiment participants with various abilities in short- and long-term memory abilities. In addition, a variety of experimental situations can be examined. The list of parameters is shown in Table II.

TABLE I. RULES OF THE MODEL

Rule	Function
Presentation rule	presents an item and encodes it into the short-term memory
Two erasing rules	erase items from the short-term memory after the time limit for holding items has passed, and erase items from the short-term memory when the number of items has exceeded the working memory capacity
Rehearsal rule	performs rehearsals of items in the short-term memory
Encoding rule	encodes items into long-term memory when the number of rehearsals exceeds a threshold value
Two reporting rules	report items from the short-term and long-term memories when asked to report memorized items after all items have been presented
Two rules	for stopping the system and increasing the time counter

C. Class practice

This class practice was implemented as follows. The practice here was part of a cognitive science lesson directed by the first author. A total of 118 participants joined the class.

TABLE II. PARAMETERS OF THE MODEL

Parameter	Function
Presentation interval	controls an interval between two successive item presentations
Rehearsals for encoding	specifies the number of rehearsals needed for encoding items into the long-term memory
Working memory capacity	specifies the number of items that can be simultaneously stored in the short-term memory; when the number of items exceeds this limit, the oldest item that was stored earliest is erased from the short-term memory
Holding time	specifies a time limit for holding items in the short-term memory; when no rehearsals are performed beyond the time limit, the item is erased from the short-term memory

The participants first took part in the serial position effect experiment in groups. At three-second intervals, 20 words were presented, and the participants were asked to list as many words as possible immediately after memorizing them.

Figure 2 shows the results of the experiment. The pattern does not show a typical U-shape, but in the overall pattern, the primacy and recency effects can be confirmed.

Next, the participants attended a lecture on the dual-storage model theory that explains the serial position effect. The lecture also presented typical experimental results demonstrating the serial position effect in previous research.

After the lecture, the model for simulation was distributed to each participant. Each participant was able to simulate experiments with a variety of experimental situations and experiments by experiment participants of various abilities by freely setting parameters.

The participants were given the following two assignments.

III. ASSIGNMENTS

We performed two assignments. The first is a simple assignment, followed by a more advanced and complex second assignment.

A. First assignment

1) Tasks: In Assignment 1, the participants were divided into five groups, Groups A to E, each of which addressed the following issues:

- **Group A** Examination of the effect of the time interval of the presented words on experimental results
- **Group B** Examination of the effect of rehearsal ability (required activities for transfer to the long-term memory) on experimental results
- **Group C** Examination of the effect of capacity ability to maintain words in the short-term memory on experimental results
- **Group D** Examination of the effect of retention ability of the short-term memory on experimental results
- **Group E** Examination of the effect of the number of presented words on experimental results.

The participants were asked to submit a research report consisting of (1) hypotheses, (2) experimental designs, (3) experimental results, and (4) interpretations. The hypotheses were submitted prior to the simulation, and care was taken not to change the hypotheses after the simulation.

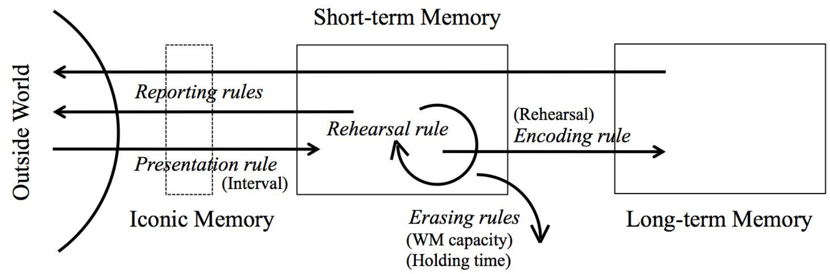

Figure 1. Summary of the production system model. Italics indicate production rules, and parentheses indicate rule parameters.

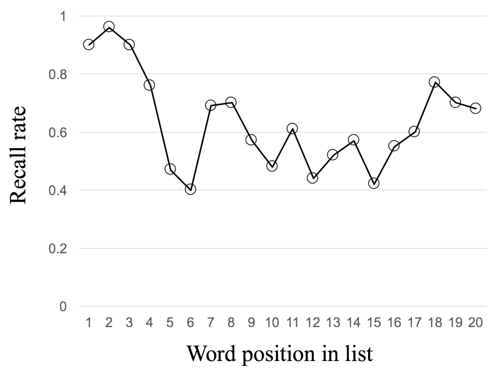

Figure 2. Experimental results by participants.

2) Results of the simulations: Figure 3 shows the results of the simulations performed while controlling the four parameters listed in Table II.

Some interesting patterns can be found.

- **Rehearsals** As the number of rehearsals required to transfer the items stored in the short-term memory to the long-term memory increases, the recall rate of words that were presented from the first to middle half of the list decreases. On the other hand, the recall ratio of words presented at the end does not decrease.
- **Presentation interval** Patterns similar to those found in the control of required rehearsals are confirmed. However, for words that were presented at one-second intervals, the recall ratio of words presented from the first to middle half of the list decreases, but, oppositely, the ratio for words presented at the end increases.

These phenomena can be understood based on explanations about why primacy and recency effects emerge in the preceding literature.

The participants manipulated the relevant parameters according to a topic set for each group, and confirmed results similar to those indicated in Figure 3. Based on these simulation results, the participants examined their initial hypotheses.

3) Scores of the participants' reports: Two expert coders analyzed the participants' reports. A perfect score was two points; and if any of the following checkpoints applied, one point was deducted.

- The hypothesis is untestable, or cannot be understood.
- The experimental design is inadequate for examining the hypothesis, i.e., incorrect factor control that cannot test the hypothesis.
- The experiment has an incorrect factorial design.
- The simulation results are obviously strange.

The data of 115 participants among 118 who submitted a report were analyzed. Table III shows the distribution of scores. It is confirmed that about two-thirds of participants planned adequate experiments based on an appropriate hypothesis, and assessed the simulation results properly.

TABLE III. DISTRIBUTION OF REPORT SCORES IN ASSIGNNMET 1

Score	0	1	2
Number (rate)	10 (0.09)	35 (0.30)	70 (0.61)

B. Second assignment

1) Tasks: In Assignment 2, based on the results of Assignment 1, the participants were asked to create a more complex hypothesis on why the primacy and recency effects would appear. To test the hypothesis more deeply, they would need to perform 2 x 2 factorial design experiments.

2) Scores of participants reports: The participants were told to submit the same style of report as in Assignment 1. The submitted reports were scored based on the same criterion as in Assignment 1. The data of 112 participants who submitted the report were analyzed. Table IV shows the distribution of scores.

TABLE IV. DISTRIBUTION OF REPORT SCORES IN ASSIGNNMET 2

Score	0	1	2
Number (rate)	6 (0.05)	43 (0.38)	63 (0.56)

IV. DISCUSSION AND CONCLUSIONS

This paper describes an example class practice that used model-based exercises in a psychology class in which participants investigated the serial position effect of the human memory. The class introduced a rule-based cognitive model built based on the dual-storage model theory as a typical theory of the human memory. This model can reproduce the primacy and recency effects in the serial position effect. The participants themselves manipulated the parameters of the model and performed simulations that examined psychological experiments with a variety of experimental settings and experiments

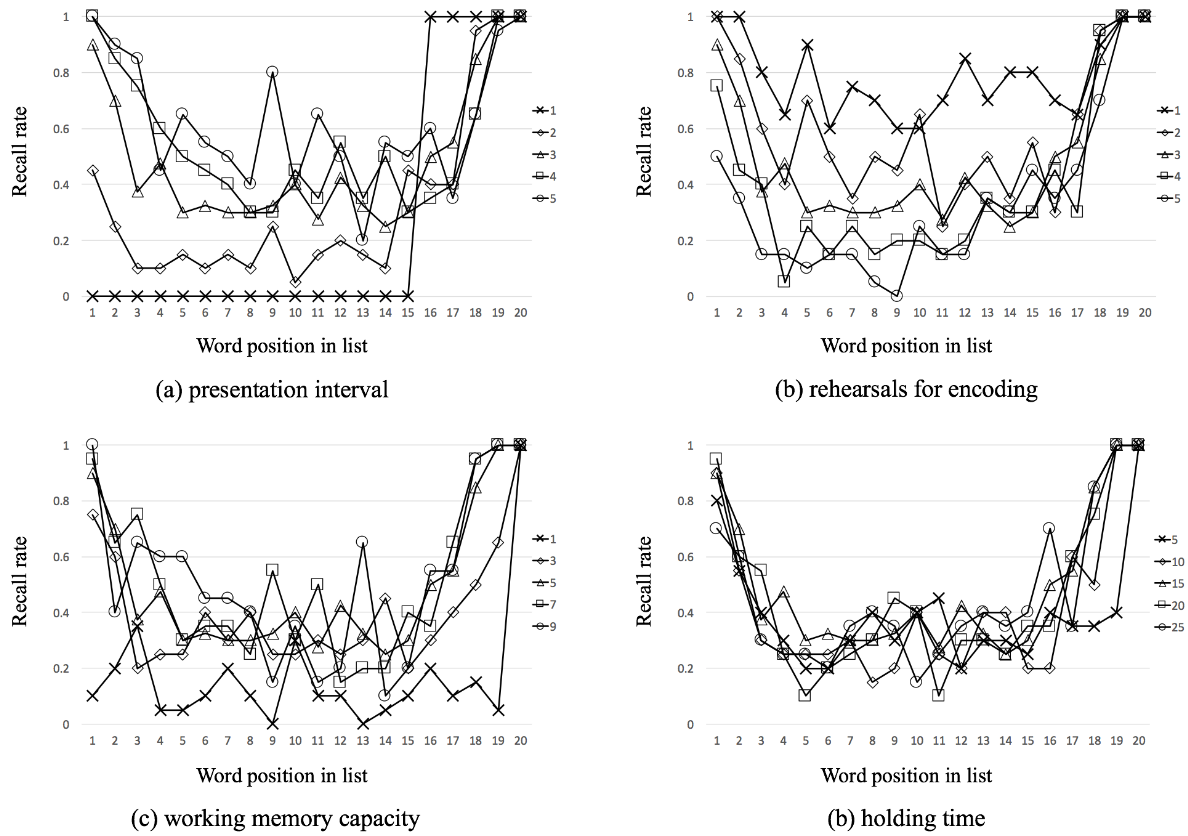

Figure 3. Results of computer simulations performed while controlling four parameters. Four parameters, (a) word presentation interval time, (b) rehearsals required for encoding items into the long term memory, (c) the number of items possible to be stored in the short term memory, and (d) holding time possible to be maintained in the short term memory, were controlled. The legend shows values of each parameter.

by participants of various working memory capabilities. After the exercise, the participants worked on research reports that followed typical psychological exploration patterns: hypotheses, experimental designs, experimental results, and discussion. Analysis of the reports confirmed that about two-thirds of the participants experienced good exploration processes and were successful in compiling the research reports.

This case practice illustrates the value of introducing the model-based approach in cognitive science, and more broadly, in cognitive psychology classes. In many psychology classes, experiments for training are widely used, but computational models are not always practiced. The lessons introduced in this paper are less costly to introduce, and it is likely that they can be applied in psychology-related lessons.

Many cognitive science researchers employ the constructive approach. On the other hand, there are not many teachers who adopt the model-based approach in education. Yet, as the analytical and constructive methods are two pillars of empirical science, it is important to give psychology students a fundamental understanding of the model-based approach as part of the general knowledge and skills they need as junior researchers investigating the human mind.

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